In Control: A Statistical Process Analysis

Ryan Mersereau

NC State University

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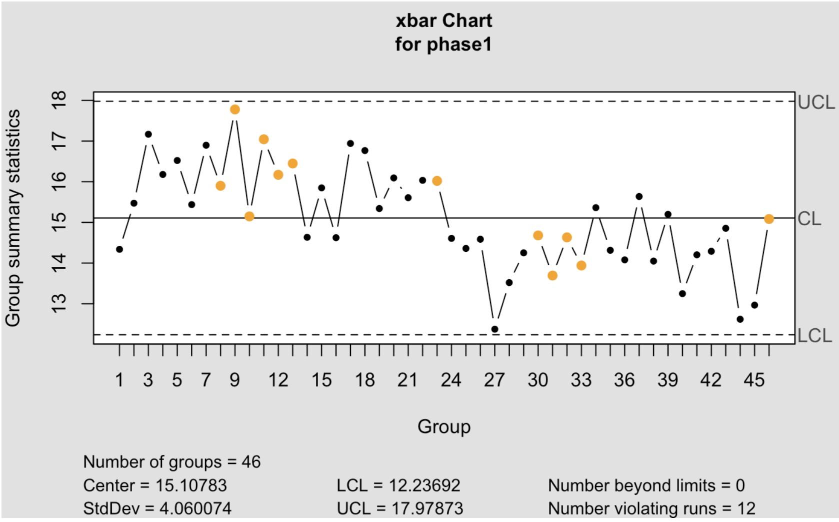
The data assigned for this project contained 74 observations or samples (m) with a subgroup size of 18 (n) for each sample. The data was split into Phase 1 and Phase 2 two, with the first 46 samples being attributed to Phase 1 and the following 28 samples attributed to Phase 2. To determine the normality of the data, a histogram and Q-Q Plot of all data points were constructed. The histogram appeared bell-shaped with no apparent skewness, and the Q-Q Plot had few noticeable outliers. A Shapiro-Wilk normality test of the data returned a p-value of 0.373, which is too large to conclude the abnormality of the data. Therefore, we conclude that the data is approximately normal.

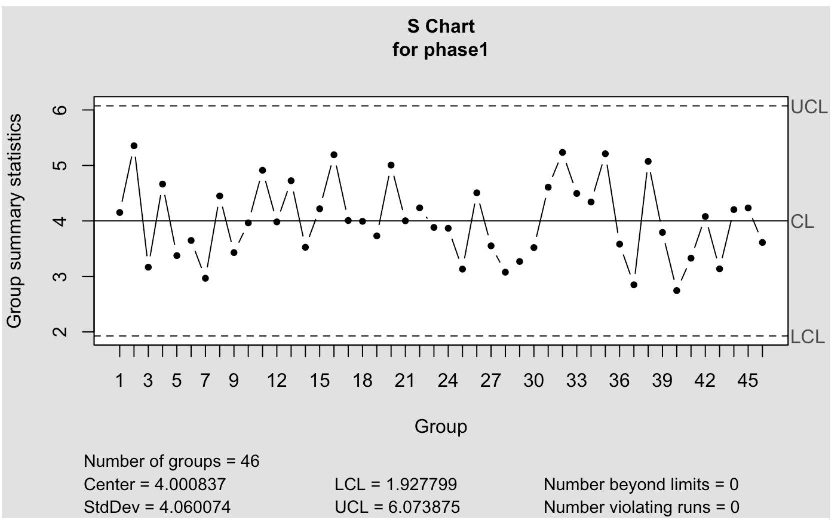
Constructing Control Charts

Because we are dealing with a large subgroup size(18), I constructed Xbar and S charts. Using standard deviation to measure data variation is generally better than using range when subgroup sizes are large (>10) or if subgroup size is non-constant. The X Bar chart constructed with Phase 1 data has a center of 15.107, a standard deviation of 4.06, an LCL of 12.236, and a UCL of 17.978. The S chart constructed has a center of 4.0008 and a standard deviation of 4.06.

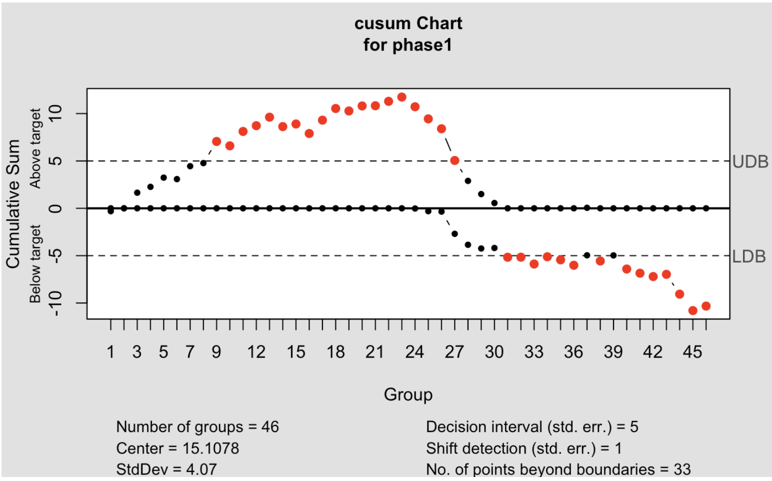
Assessments and Measures

For the S chart, no points plot out of control and no conditions are violated. For the Xbar chart, no points plot out of control, but 8 consecutive points plot on one side of the center line, violating the process run. If we look closely at the control chart, we see a shift in the process means around halfway through the Phase 1 data, which results in several consecutive points that fall above or below the center line.





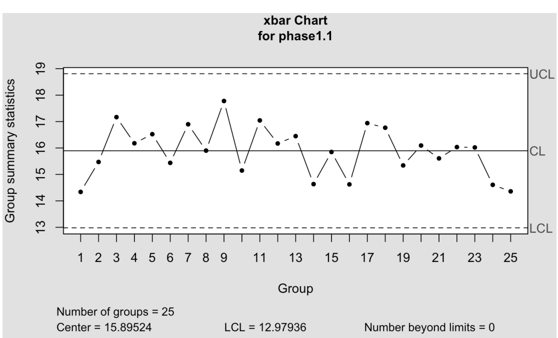
If we split the Phase 1 data into two groups around group 25, we find that the first 25 data points have a center of 15.895, whereas the last 21 points have a center of 14.17. This is a considerable difference in the process mean, and may be indicative of a large shift in the process mean due to several factors leading to a process not in control. Making control charts using this split phase 1 data results in control charts that are in control and do not violate any guidelines, therefore this may be useful if we are told there are no assignable causes of variation. Additionally, by constructing a cumulative sum chart using the mean and standard deviation found from the Xbar chart, the shift in mean throughout the phase 1 data is evident, as many points plot out of control.

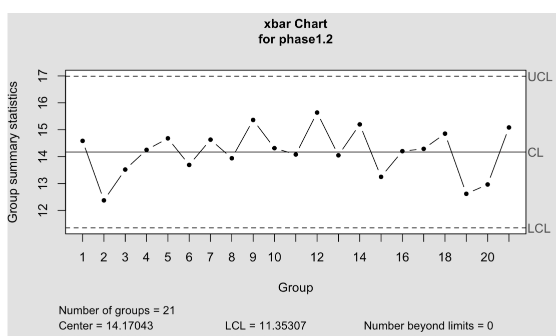


Results

Parameters and Process Capability

The estimated population parameters found from the Xbar chart are a mean of 15.107 and a standard deviation of 4.06. Given the above control charts, I would not say these estimates are reliable for the population, given the shift in the mean of the Phase 1 data, and we can't soundly conclude that the process is in control. However, If we separate the Phase 1 data into two parts, the results for each part of the data are reliable because each of these charts is in control. The parameter estimates for the population mean and standard deviation for the first split of Phase 1 are 15.895 and 4.123. For the second split of Phase 1, these estimates are 14.17 and 3.984.





The Process capability ratio using the upper and lower parameters of 13.5 and 18.5 respectively, and the standard deviation from the Xbar chart of 4.06, Cp was found to be 0.205. This value is much lower than 1, meaning that this process cannot reliably produce units that meet the desired parameters. To determine if the process is off-center, we can also calculate Cpk by taking the minimum value between Cpu and Cpl. This was found to be 0.132. Since Cp is greater than Cpk, this process is also slightly off-center.

Calibration & New Data

As we saw with the calibration data where there is clear evidence of a shift in process mean over time with samples, we see the same thing as we add in the new data from Phase 2. The Phase 2 data appears to have a sudden shift in process mean, where the first half of samples continues with the latter half of the Phase 1 data, and then the second half of Phase 2 data increases dramatically, scattering around a much higher process mean of about 18. This leads to a few points that plot outside of control limits on the new S chart using the limits from the calibration data. While these can be addressed and control limits can be adjusted, the new Xbar chart contains 8 points that plot outside the control limits, indicating a clear out-of-control process in Phase 2 when using the specified limits from the Phase 1 data.

Discussion

As mentioned above, choosing the right control charts is a critical decision in process management, impacting the effectiveness of process monitoring and maintaining consistency in production. Several factors come into play when considering whether to use Xbar and R charts or Xbar and S charts. Xbar and R charts are commonly employed when the subgroup size is relatively small (typically less than 10) or when individual measurements can be easily obtained. The R chart, which tracks the range within each sample, is particularly useful for detecting variability due to factors such as measurement error. On the other hand, Xbar and S charts are preferred when sample subgroup sizes are larger or when the data distribution is not normal. The S chart, which monitors the standard deviation within each sample, is more robust against non-normality compared to the R chart. However, the S chart requires larger sample sizes to achieve comparable sensitivity to the R chart. Overall, the choice between Xbar and R charts and Xbar and S charts hinges on factors such as sample size, data distribution, and the desired level of sensitivity to process variations. Because S charts are significantly preferred when the subgroup size is large, I chose to construct Xbar and S charts using standard deviation, although it is important to consider several different control charts during the monitoring process.

Increasing the sensitivity of these Xbar and S charts has pros and cons. Increased sensitivity allows for the detection of smaller deviations from the mean, enabling proactive adjustments to processes before they result in significant defects or variations. This can lead to improved quality control or save money and time in a practical setting. However, it may be important to have some sort of balance as excessively sensitive control charts may also trigger false alarms. This can lead to unnecessary interventions and disruptions in production. Increasing sensitivity typically involves reducing the control limits, which could increase the likelihood of Type I errors (false positives). Therefore, we should decide to increase sensitivity after considering the trade-offs between early detection of process variations and the potential for increased Type I error. For this process, it may be beneficial to keep the sensitivity of the control charts high, because we see shifts in the process mean in the Phase 1 and Phase 2 data and it is important to detect smaller shifts in the process mean.